PRELIMINARY AMENDMENT
U.S. Appln No. 10/089,547

REMARKS

Applicants herewith seek entry of amendments corresponding to those made during the international stage per Article 11 et al. No new matter has been entered.

Entry and consideration of this Amendment are respectfully requested.

Respectfully submitted,

Richard C. Turner
Registration No. 29,710

SUGHRUE MION, PLLC
2100 Pennsylvania Avenue, N.W.
Washington, D.C. 20037-3213
Telephone: (202) 293-7060
Facsimile: (202) 293-7860

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APPENDIX

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

Pages 9-10, amend paragraph 3 as follows:

In order to solve the above-mentioned problems, the present invention provides axial magnetic bearing apparatus in which a rotary disc made of a magnetic material is fixedly attached to a rotating shaft, while a pair of electromagnetic stators in each of which a ring-like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of the rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of the rotating shaft, magnetic attraction force is made to act between the rotary disc and each of the electromagnetic stators so as to bear the rotating shaft in a target position distant from the electromagnetic stators and in non-contact therewith, wherein [a deep groove or through holes for forming an air layer having large magneto-resistance are provided in a vicinity of an axial center of the rotary disc so as to extend from an outer circumferential portion of the rotary disc toward the rotating shaft] <u>a deep groove for forming an air layer having large magneto-resistance is provided in a vicinity of an axial center of the rotary disc so as to extend from an outer circumferential portion of the rotary disc toward the rotating shaft, and a bottom portion of the deep groove is located to be closer to the above-mentioned rotating shaft than inside magnetic pole teeth of the above-mentioned electromagnetic stators. In addition, according to the present invention, the above-mentioned deep groove is formed all over the outer circumference of the above-mentioned rotary disc. In addition, according to the present</u>

invention, fan-shaped through holes for forming an air layer having large magneto-resistance are provided in the vicinity of an axial center of the above-mentioned rotary disc so as to extend from an outer circumferential portion of the above-mentioned rotary disc to the above-mentioned rotating shaft, while walls of rotary disc pieces located on axially opposite sides of this through holes are formed as solid walls having no through hole axially.

Page 10, amend paragraphs 2 and 3 as follows:

Further, according to the present invention, the deep groove is formed all over an outer circumference of the rotary disc, while an inner diameter of the [deep groove is designed to be smaller than an inner diameter of each of inside magnetic pole teeth of the electromagnetic stators] a deep groove for forming an air layer having large magneto-resistance is provided in a vicinity of an axial center of the rotary disc so as to extend from an outer circumferential portion of the rotary disc toward the rotating shaft, and a bottom portion of the deep groove is located to be closer to the above-mentioned rotating shaft than inside magnetic pole teeth of the above-mentioned electromagnetic stators. In addition, according to the present invention, the above-mentioned deep groove is formed all over the outer circumference of the above-mentioned rotary disc. In addition, according to the present invention, fan-shaped through holes for forming an air layer having large magneto-resistance are provided in the vicinity of an axial center of the above-mentioned rotary disc so as to extend from an outer circumferential portion of the above-mentioned rotary disc to the above-mentioned rotating shaft, while walls of rotary disc pieces located on axially opposite sides of this through holes are formed as solid walls having no through hole axially.

Page 12, amend paragraph 1 as follows:

As a result, magnetic flux and leakage flux entering the inside of the rotary disc through the surface of rotary disc not opposed to any one of the inside magnetic pole teeth and the outside magnetic teeth of the electromagnetic stators are relieved so that the magnetic flux density in the inside magnetic pole tooth and the outside magnetic pole tooth of each of the electromagnetic stators can be increased. Accordingly, the electric energy supplied to the electromagnetic coils can be [more] effectively utilized to control the position of the rotating shaft.

Pages 12-13, amend paragraph 2 as follows:

Further, according to the present invention, slits large enough to increase radial magneto-resistance are provided at several places in outer circumferential portions of the electromagnetic stators. Accordingly, magnetic interference between two magnetic circuits formed by the respective electromagnetic stators is relieved. As a result, it is possible to relieve the formation of an abnormal magnetic circuit extending from one electromagnetic stator to the other electromagnetic stator through the casings or the collar and extending from the other electromagnetic stator to the one electromagnetic stator through the rotor disc. Thus, electric energy supplied to the electromagnetic coils is [more] effectively utilized to control the position of the rotating shaft so that it is possible to improve the control performance.

Page 13, amend paragraph 1 as follows:

Further, according to the present invention, an outer circumferential groove for forming an air layer having large magneto-resistance is provided in a portion of each of the outside

magnetic pole teeth of the electromagnetic stators not opposed to the rotary disc so as to extend axially from a side where the rotary disc is located. Accordingly, magnetic interference between two magnetic circuits formed by the respective electromagnetic stators is relieved, and the magnetic flux density in the inside magnetic pole tooth and the outside magnetic pole tooth of each of the electromagnetic stators can be increased. As a result, it is possible to relieve the formation of an abnormal magnetic circuit extending from one electromagnetic stator to the other electromagnetic stator through the casings or the collar and extending from the other electromagnetic stator to the one electromagnetic stator through the rotor disc. Thus, electric energy supplied to the electromagnetic coils is [more] effectively utilized to control the position of the rotating shaft so that it is possible to improve the control performance.

Page 14, amend paragraph 1 as follows:

Further, according to the present invention, an outer diameter of each of the electromagnetic stators is formed to have substantially as large as an outer diameter of the rotary disc, and a ring made of a non-magnetic material having a radial thickness enough to form a layer with large magneto-resistance is interposed between an outer circumferential portion of each of the electromagnetic stators and an inner circumferential portion of corresponding one of the casings to which the electromagnetic stator is attached. Accordingly, two magnetic circuits formed by the respective electromagnetic stators are insulated from each other magnetically perfectly, and the magnetic flux density in the inside magnetic pole tooth and the outside magnetic pole tooth of each of the electromagnetic stators can be increased. As a result, it is possible to more surely prevent the formation of an abnormal magnetic circuit extending from

one electromagnetic stator to the other electromagnetic stator through the casings or the collar and extending from the other electromagnetic stator to the one electromagnetic stator through the rotor disc. Thus, electric energy supplied to the electromagnetic coils is [more] effectively utilized to control the position of the rotating shaft so that it is possible to improve the control performance.

Pages 18-19, amend paragraph 2 as follows:

Then, as a characteristic portion of the present invention, the deep groove 16 is provided near the axial center of the rotary disc 2 fixedly attached to the rotating shaft 1, so as to cover the outer circumference of the rotary disc 2. The inner diameter of the deep groove 16 is formed to be smaller than the inner diameter of each of the inside magnetic pole teeth 11. That is, the deep groove 16 is located so that the bottom portion thereof is closer to the rotating shaft 1 than the inside magnetic pole teeth 11 of the electromagnetic stators 7a and 7b. Due to this deep groove 16, an air layer is formed with a certain suitable width in the axial direction so as to have sufficiently large magneto-resistance. Accordingly, the one magnetic circuit 13 formed by the electromagnetic stator 7a and the rotary disc 2 and the other magnetic circuit 13 formed by the electromagnetic stator 7b and the rotary disc 2 are insulated from each other magnetically. As a result, formation of an abnormal magnetic circuit designated by the reference numeral 14 in Fig. 9 can be relieved without increasing the number of parts, and a magnetic circuit is made independent for each of the electromagnetic stators 7a and 7b. Thus, the electric energy supplied to the electromagnetic coils 10 can be used effectively for position control of the rotating shaft 1.

Page 20, amend paragraph 4 as follows:

That is, in this Mode 2, as shown in Figs. 2A and 2B, the rotary disc 2 has, on its opposite sides, sleeves 6 to be fixedly attached to the rotating shaft 1. Slit-like through holes 17 extending from the outer circumferential portion of the rotary disc 2 to the outer circumferential portion of the rotating shaft 1 are provided at several places in the vicinity of the axial center of the rotary disc 2. Incidentally, these through holes 17 are formed in positions where the through holes 17 do not unbalance the rotary disc 2 when the rotary disc 2 rotates at a high speed. In addition, an air layer formed by each of these <u>fan-shaped</u> slit-like through holes 17 is formed with a certain suitable diameter to have sufficiently large magneto-resistance. In addition, in Fig. 2B, the reference numeral 17a represents a portion 17a where no slit-like through hole 17 is provided. The portion 17a plays a role of connection between rotary disc pieces 3 and 3. Incidentally, the other configuration is similar to that in Mode 1, and hence description thereof will be omitted.

Page 35, amend paragraph 2 as follows:

In addition, the present invention is not limited to the above-mentioned respective modes, but includes a wide variety of other modifications. [The present invention has a feature in that the two electromagnetic stators 7 are relieved or prevented from magnetic interference, and the stiffness of a rotor is prevented from being lowered even at the time of high speed rotation. Therefore, for example, in Mode 2, the slit-like through holes 17 for forming an air layer having large magneto-resistance are provided from the outer diameter portion of the rotary disc 2 to the vicinity of the axial center of the rotary disc 2. However, in place of these slit—like through

holes 17, circular through holes may be provided at several places to extend from the outer circumferential portion of the rotary disc 2. In this case, since the through holes can be formed easily with a drill or the like, the workability is good. Alternatively, in Mode 2, not always by through holes, but by a deep groove which is deeper than the inner diameter of each of the inside magnetic pole teeth 11 of the electromagnetic stators 7 and which does not reach the outer circumferential portion of the rotating shaft 1, it is also possible to attain the intended objects] For example, in Node 2, not always by through holes, but by a deep groove which is deeper than the inner diameter of the inside magnetic pole teeth 11 of the electromagnetic stators 7 and which does not reach the outer circumferential portion of the rotating shaft 1, it is also possible to attain the intended objects.

Page 37, amend paragraph 2 as follows:

Further, according to the present invention, a distance between a surface of the rotary disc located in a position not opposed to any one of an inside magnetic pole tooth and an outside magnetic pole tooth of corresponding one of the electromagnetic stators and a surface of the corresponding electromagnetic stator opposed to the surface of the rotary disc is formed to be larger than a distance between a surface of the rotary disc located in a position opposed to each of the inside magnetic pole tooth and the outside magnetic pole tooth of the corresponding electromagnetic stator and a surface of the corresponding electromagnetic stator opposed to the surface of the rotary disc. Accordingly, magnetic flux entering the inside of the rotary disc through the surface of rotary disc not opposed to any one of the inside magnetic pole teeth and the outside magnetic teeth of the electromagnetic stators, and leakage flux escaping to an

atmosphere are relieved, so that the magnetic flux density in the inside magnetic pole tooth and the outside magnetic pole tooth of each of the electromagnetic stators can be increased. Accordingly, the electric energy supplied to the electromagnetic coils can be [more] effectively utilized to control the position of the rotating shaft.

Pages 39-40, amend paragraph 2 as follows:

Further, according to the present invention, an outer diameter of each of the electromagnetic stators is formed to have substantially as large as an outer diameter of the rotary disc, and a ring made of a non-magnetic material having a radial thickness enough to form a layer with large magneto-resistance is interposed between an outer circumferential portion of each of the electromagnetic stators and an inner circumferential portion of corresponding one of the casings to which the electromagnetic stator is attached. Accordingly, two magnetic circuits formed by the respective electromagnetic stators are insulated from each other magnetically perfectly, and the magnetic flux density in the inside magnetic pole tooth and the outside magnetic pole tooth of each of the electromagnetic stators can be increased. As a result, it is possible to [more] surely prevent the formation of an abnormal magnetic circuit extending from one electromagnetic stator to the other electromagnetic stator through the casings or the collar and extending from the other electromagnetic stator to the one electromagnetic stator through the rotor disc. Thus, electric energy supplied to the electromagnetic coils is more effectively utilized to control the position of the rotating shaft so that it is possible to improve the control performance.

Page 40, amend paragraph 1 as follows:

Further, according to the present invention, a collar made of a non-magnetic material for relatively positioning where the pair of electromagnetic stators are attached is provided between the pair of electromagnetic stators. Accordingly, two magnetic circuits formed by the respective electromagnetic stators are insulated from each other magnetically. As a result, it is possible to [more] surely prevent the formation of an abnormal magnetic circuit extending from one electromagnetic stator to the other electromagnetic stator through the collar and extending from the other electromagnetic stator to the one electromagnetic stator through the rotor disc. Thus, electric energy supplied to the electromagnetic coils is effectively utilized to control the position of the rotating shaft so that it is possible to improve the control performance.

IN THE CLAIMS:

The claims are amended as follows:

Claim 1 (Amended) Axial magnetic bearing apparatus in which a rotary disc made of a magnetic material is fixedly attached to a rotating shaft, while a pair of electromagnetic stators in each of which a ring-like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of said rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of said rotating shaft, magnetic attraction force is made to act between said rotary disc and each of said electromagnetic stators so as to bear said rotating shaft in a target position distant from said electromagnetic stators and in non-contact therewith, said axial magnetic bearing apparatus being characterized in that [a deep groove or through holes for forming an air layer having large magneto-resistance are provided in

a vicinity of an axial center of said rotary disc so as to extend from an outer circumferential portion of said rotary disc toward said rotating shaft] a deep groove for forming an air layer having large magneto-resistance is provided in a vicinity of an axial center of said rotary disc so as to extend from an outer circumferential portion of said rotary disc toward said rotating shaft, and a bottom portion of said deep groove is located to be closer to said rotating shaft than inside magnetic pole teeth of said electromagnetic stators.

Claim 2 (Amended) Axial magnetic bearing apparatus according to Claim 1, characterized in that [said deep groove is formed all over an outer circumference of said rotary disc, while an inner diameter of said deep groove is smaller than an inner diameter of each of inside magnetic pole teeth of said electromagnetic stators] said deep groove is formed all over the outer circumference of said rotary disc.

Claim 3 (Amended) Axial magnetic bearing apparatus [according to Claim 1, characterized in that each of said through holes has a slit shape extending from said outer circumferential portion of said rotary disc to an outer circumferential portion of said rotating shaft] in which a rotary disc made of a magnetic material is fixedly attached to a rotating shaft, while a pair of electromagnetic stators in each of which a ring-like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of said rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of said rotating shaft, magnetic attraction force is made to act between said rotary disc and each of said electromagnetic stators so as to bear said rotating shaft in a target position distant from said electromagnetic stators and in non-contact therewith, said thrust magnetic bearing apparatus being characterized in that fan-shaped through holes for forming an air layer having large magneto-resistance are provided in a vicinity of an axial center of said rotary disc so as to extend from an outer circumferential portion of said rotary disc to said rotating shaft, while walls of rotary disc pieces located on axially opposite sides of said through holes are formed as solid

walls having no through hole axially.

Claim 4 (Amended) Axial magnetic bearing apparatus [according to any one of Claims 1 through 3, characterized in that a distance between a surface of said rotary disc located in a position not opposed to any one of an inside magnetic pole tooth and an outside magnetic pole tooth of corresponding one of said electromagnetic stators and a surface of said corresponding electromagnetic stator opposed to said surface of said rotary disc is formed to be larger than a distance between a surface of said rotary disc located in a position opposed to each of said inside magnetic pole tooth and said outside magnetic pole tooth of said corresponding electromagnetic stator and a surface of said corresponding electromagnetic stator opposed to said surface of said rotary disc] in which a rotary disc made of a magnetic material is fixedly attached to a rotating shaft, while a pair of electromagnetic stators in each of which a ring-like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of said rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of said rotating shaft, magnetic attraction force is made to act between said rotary disc and each of said electromagnetic stators so as to bear said rotating shaft in a target position distant from said electromagnetic stators and in non-contact therewith, said thrust magnetic bearing apparatus being characterized in that a distance between a surface of said rotary disc existing in a position not opposed to any one of an inside magnetic pole tooth and an outside magnetic pole tooth of corresponding one of said electromagnetic stators and a surface of said corresponding electromagnetic stator opposed to said surface of said rotary disc is formed to be larger than a distance between a surface of said rotary disc existing in a position opposed to each of said inside magnetic pole tooth and said outside magnetic pole tooth of said corresponding electromagnetic stator and a surface of said corresponding electromagnetic stator opposed to said surface of said rotary disc.

Claim 5 (Amended) Axial magnetic bearing apparatus [according to any one of Claims 1 through 4, characterized in that slits large enough to increase radial magneto-resistance are provided at several places in outer circumferential portions of said electromagnetic stators] <u>in which a rotary disc made of a magnetic material is fixedly attached to a rotating shaft, while a pair of electromagnetic stators in each of which a ring—like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of said rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of said rotating shaft, magnetic attraction force is made to act between said rotary disc and each of said electromagnetic stators so as to bear said rotating shaft in a target position distant from said electromagnetic stators and innon-contact therewith, said thrust magnetic bearing apparatus being characterized in that slits large enough to increase radial magneto-resistance are provided at several places in outer circumferential portions of said electromagnetic stators</u>.

Claim 6 (Amended) Axial magnetic bearing apparatus [according to any one of Claims 1 through 5, characterized in that an outer circumferential groove for forming an air layer having large magneto-resistance is provided in a portion of each of said outside magnetic pole teeth of said electromagnetic stators not opposed to said rotary disc so as to extend axially from a side where said rotary disc is located] <u>in which a rotary disc made of a magnetic material is fixedly attached to a rotating shaft, while a pair of electromagnetic stators in each of which a ring-like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of said rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of said rotating shaft, magnetic attraction force is made to act between said rotary disc and each of said electromagnetic stators so as to bear said rotating shaft in a target position distant from said electromagnetic stators and in non-contact therewith, said thrust magnetic bearing apparatus being characterized in that outer circumferential grooves for forming an air layer having large magneto-resistance are provided respectively in portions of outside magnet</u>

pole teeth of said electromagnetic stators not opposed to said rotary disc, so as to extend axially from a side where said rotary disc is located.

Claim 7 (Amended)Axial magnetic bearing apparatus [according to any one of Claims 1 through 6, characterized in that an outer diameter of each of said electromagnetic stators is formed to have substantially as large as an outer diameter of said rotary disc, and a ring made of a non-magnetic material having a radial thickness enough to form a layer with large magneto-resistance is interposed between an outer circumferential portion of each of said electromagnetic stators and an inner circumferential portion of corresponding one of said casings to which said electromagnetic stator is attached] in which a rotary disc made of a magnetic material is fixedly attached to a rotating shaft, while a pair of electromagnetic stators in each of which a ring-like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of said rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of said rotating shaft, magnetic attraction force is made to act between said rotary disc and each of said electromagnetic stators so as to bear said rotating shaft in a target position distant from said electromagnetic stators and in non—contact therewith, said thrust magnetic bearing apparatus being characterized in that an outer diameter of each of said electromagnetic stators is formed to be substantially as large as an outer diameter of said rotary disc, and a ring made of a non-magnetic material having a radial thickness large enough to form a layer with large magneto-resistance is interposed between an outer circumferential portion of each of said electromagnetic stators and an inner circumferential portion of corresponding one of said casings to which said electromagnetic stator is attached.

Claim 8 (Amended) Axial magnetic bearing apparatus according to [any one of Claims 1 through 7, characterized in that a collar made of a non—magnetic material for relatively positioning where said pair of electromagnetic stators are attached is provided between said pair of electromagnetic stators] in which a rotary disc made of a magnetic material is fixedly attached

to a rotating shaft, while a pair of electromagnetic stators in each of which a ring—like electromagnetic coil for generating magnetomotive force is inserted into a coil slot are fixed to casings respectively so as to be located on opposite sides of said rotary disc with suitable very small distances, and on the basis of an output signal of a displacement sensor for measuring axial displacement of said rotating shaft, magnetic attraction force is made to act between said rotary disc and each of said electromagnetic stators so as to bear said rotating shaft in a target position distant from said electromagnetic stators and in non-contact therewith, said thrust magnetic bearing apparatus being characterized in that a collar made of a non-magnetic material for relatively positioning attachment of said pair of electromagnetic stators is provided between said pair of electromagnetic stators.